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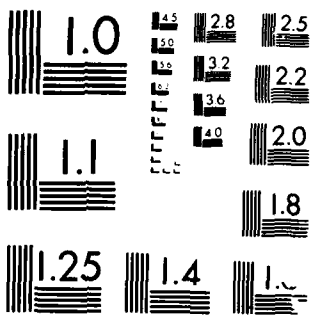

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T. B. [redacted]
J. S. Waldock

University of Leicester
Department of Physics
University Road
Leicester, LE1 7RH, U.K.

20 September 1987

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Ionospheric Effects Branch
Ionospheric Physics Division

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ROBERT A. SKRIVANEK
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Plasma drifts measured by SABRE in the E-region have been compared with those obtained from HILAT, at an altitude of 800 km, during a pass on March 1 1984. Results are not consistent with perfect mapping of the electric field between the two regions. Furthermore, no field-aligned current signature is observed by SABRE.

A comparison of E-region plasma drifts measured by SABRE and F-region scintillations measured by the NNSS satellites suggests that the latter may be related to regions of reduced electric field in the F-region. This is consistent with the presence of field-aligned currents which produce kilometre-scale structure in the F-region plasma.

Mean plasma convection patterns in the E-region have been derived as a function of the IMF components By and Bz and the magnetic index Kp. Convection flows are much stronger for southward Bz. The time of the evening convection reversal occurs at later local times for increasingly negative By. As Kp increases radar measurements occur during a higher proportion of the day and the evening convection reversal also moves to earlier local times.

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STUDIES OF IONOSPHERE/MAGNETOSPHERE DYNAMICS USING SABRE AND HILAT

INTRODUCTION

The scientific objectives of the joint SABRE/HILAT project are designed to provide new insight into the physics of E and F region high latitude plasma irregularities and their dependence on ambient properties of the medium, such as the large-scale density and velocity structure. The plasma gradients associated with these phenomena provide a suitable environment for certain instability processes to generate kilometre-scale irregularities, which are responsible for the scintillation effects which degrade trans-ionospheric UHF communication links. It is therefore important that the generation, transport and decay of these irregularities are more fully understood. This requires measurement of the various irregularity parameters by coordinated multi-technique experiments. One of these is the HILAT satellite, which was launched on June 27 1983, and provides in-situ measurements of scintillation structure and other particle and field data with high time resolution along the track of its orbit. The satellite has a velocity of approximately 7 km/s and hence this data set is effectively a snapshot of the ionosphere along the satellite trajectory. It therefore becomes difficult to separate spatial and temporal variations and the satellite may be unable to resolve the source region, since the irregularities are not static. Consequently it is necessary to coordinate the HILAT measurements with ground-based observations such as those made by the Sweden and Britain Auroral Radar Experiment (SABRE).

SABRE is a bistatic auroral radar experiment, similar to STARE but situated at lower latitudes, covering the L-shell range of approximately 4 to 6. The two radar installations at Wick, in Scotland, and at Uppsala, in Sweden (Figure 1), are operated by Leicester University, UK and by the Max-Planck Institut fur Aeronomie, FRG in cooperation with the Uppsala Ionospheric Observatory. The radars are able to estimate the two dimensional perpendicular electric field within their common field of view (0-12 degrees east, 64-68 degrees north geographic) with a spatial resolution of approximately 20x20 km and a temporal resolution of 20s. During times of special interest, these data are compared with measurements made by the instruments on board the HILAT satellite and with other ground-based facilities in northern Europe, such as EISCAT. The primary scientific objectives of the project are:

1. Irregularity growth rate and decay studies. It is intended to apply the time history of electric field data recorded by the SABRE together with simultaneous HILAT data to test theories of irregularity growth rate, decay rate and accumulative effects (convection of de-stabilized plasma into regions in which the ambient ionospheric conditions inhibit irregularity growth).

2. Investigation of the irregularity dependence on electrostatic turbulence. Spectral analysis of scintillation radio beacon data will be compared with SABRE and HILAT electric fields and velocity shears, together with other measured HILAT parameters.

3. Threshold studies. SABRE and radio beacon data will be compared to examine the scintillation production thresholds in relation to the

plasmapause.

4. Investigation of convection-driven re-distribution of structured plasma. This will involve comparisons of scintillation anisotropies, incoherent scatter electron density profiles and SABRE electric field patterns.

5. Comparison of the spatial and temporal features of the scintillation producing irregularities.

6. Detailed examination of the nature of the high latitude convection flow pattern under different conditions from long-timescale measurements made by SABRE. This will provide a framework within which HILAT data may be interpreted.

SABRE/HILAT COMPARISONS

A number of attempts were made to correlate HILAT measurements with those of the SABRE system. From 1-20 December 1984, a joint SABRE/STARE/HILAT campaign was held. During this period, SABRE was fully-operational and good backscatter was observed during most of the intervals of interest. Unfortunately, due to attitude problems with HILAT, the in-situ ion drift velocities measured by HILAT were unreliable and could not be used for direct comparison with the SABRE drifts. Furthermore, the times during which good E-region measurements were available from SABRE did not coincide with HILAT passes in which either the in-situ position (for particle and drift comparisons) or the F-region intersection of the line-of-sight to the beacon receiver at Tromso (for E-region effects associated with scintillation phenomena) passed across field lines threading the radar viewing area.

During a visit to AFGL in May 1985 a search was made of the HILAT database stored on microfiche. Three possible events were identified, of which just one yielded a good comparison. This event was on March 1, 1984 (day 61) between 23:17 and 23:19 UT during a southward bound pass by HILAT. The ground track of the satellite is illustrated in Figure 2. The data recorded by HILAT are illustrated in Figures 3a and b, in which the vertical lines indicate the interval during which the satellite was over the SABRE viewing area. Figure 3a shows ion density, the Tromso S4 index at 137 MHz, the total ion number flux or integral ion flux in particles/(cm ster sec), JTOT, the integral ion energy flux in keV/(cm ster sec), JETOT, and the average ion energy, EAVE, in keV, where EAVE is the ratio of JETOT to JTOT. Figure 3b shows the horizontal and vertical ion velocities measured by ion driftmeters, the RPA measured ion drift velocity together with the Tromso S4 index, which is plotted again for reference.

The ion densities (Figure 3a, lower panel) are high and significant precipitation is taking place, with the average ion energy in the range 1 to 10 keV. The scintillation amplitudes, as indicated by the Tromso S4 index, start to rise at 23:17 UT, reaching saturation level around 23:18 UT. The horizontal ion drift (Figure 3b, top panel) indicates a basically eastward convection velocity (negative value) at this time. The velocity data are compared in detail with SABRE measurements in Figure 4a and b. The auroral radar data, indicated by the horizontal lines, also suggest that the drift is basically eastwards, agreeing in broad detail with HILAT. The HILAT data have a much greater temporal resolution than those from SABRE, but the SABRE

east-west velocity component does not appear to represent an average over 20s of the HILAT measurements. Furthermore, as illustrated in Figure 4b, HILAT measures a significant northward velocity component, which is almost undetected by SABRE. The magnitude of the drift velocity measured by the auroral radar is sometimes a poor approximation to that of the electrons and SABRE may underestimate the drift speed by as much as a factor of 2 (e.g. Robinson, 1986), although the directions of the drift are thought to be accurate (e.g. Nielsen and Schlegel, 1983). If these possible sources of error are taken into account, the north-south velocity comparison improves, but the east-west comparison becomes worse. It appears that the assumption of equipotential field lines, down which the perpendicular electric field can be mapped from high altitudes to the E-region is invalid in this case. It might be expected that a non-zero parallel electric field would be associated with the observed precipitation, and that the associated field-aligned current might result in shear flows in the ionosphere. The existence of such shear flows can be investigated using the spatial resolution of SABRE and Figure 5 illustrates the two-dimensional drift velocity patterns measured by the radar from 23:17 to 23:19 UT. Each pattern is averaged over the 20s period ending at the time indicated in the lower left of each panel. However, no shear flows are apparent, an observation which has yet to be explained.

SABRE/SCINTILLATION STUDY

Due to the difficulty in locating suitable conjunctions between HILAT passes and SABRE, a suitable study of SABRE and scintillation effects could not be undertaken. Therefore, a search was made of the Naval Navigational Satellite System (NNSS) database, which provides scintillation indices at Kiruna, held by Dr.L.Kersley at the University College of Wales, Aberystwyth, UK.

A number of passes over SABRE were located and Figure 6 illustrates the satellite scintillation data recorded during one such pass. The signal strength is high and strong amplitude and phase scintillations were observed at around 18:41 on August 26, 1985 (Day 238) at an ionospheric latitude at 350 kms of around 67 degrees north. Figure 7 illustrates the SABRE data recorded at this time, as a sequence of spatial plots, each separated by 20s, with the approximate location of the satellite marked by a ringed cross. The most notable feature of these data is that the scintillations are observed when the transmission path (to Kiruna) passes through part of the F-region which maps to a region of the SABRE viewing area in which backscatter is absent, see panels at 18:40:40, 18:41 and 18:41:20 UT. In view of the fact that irregularities are evidently present in adjacent regions, it is likely that this is due to localised precipitation producing an area of enhanced conductivities. This would have the effect of 'shorting' out the electric field in this region and backscatter would be lost. This E-region signature is frequently observed when scintillations are detected in the F-region above and suggests that at these times, a field aligned current exists, producing kilometer-scale structure in the F-region plasma through a mechanism such as the current-convective instability.

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PLASMA CONVECTION PATTERNS

As a framework for the SABRE/HILAT comparisons the high latitude convection flow patterns were examined under a variety of different conditions. Mean plasma convection patterns have been deduced from long-timescale measurements made by SABRE, and Figure 8 illustrates the mean convection velocity as a function of Kp using 971 days of data in the interval Day 81, 1982 to Day 212, 1986. Several effects are immediately apparent. Firstly, radar measurements exist within a greater proportion of the day during times of higher Kp, indicating that the overall electric fields are greater. Secondly, the time at which the flow reverses in the evening sector, the Harang discontinuity, moves to earlier local times as Kp increases. Also, there are few observations of flow within the cusp, since it rarely penetrates equatorwards to the latitude range covered by the SABRE.

Recent work has investigated the dependence of the convection pattern on the polarity of the interplanetary magnetic field, using houtly averaged data provided by Dr.J.Vette of the National Space Science Data Center. 902 hours of simultaneous SABRE/IMF measurements were available between April 1982 and June 1984. Figure 9 illustrates the SABRE velocities as a function of IMF Bz at 64 degrees north, geomagnetic latitude. There are evidently fewer data at times when Bz is northward, as might be expected since reconnection at the dayside magnetopause, responsible for the large-scale convection within the magnetosphere, is then inhibited. As Bz becomes increasingly negative, the local time of the Harang discontinuity moves to earlier local times and the amplitude of the convection flow increases.

Figure 10 illustrates the variation of the flow pattern with IMF By. The evening reversal appears to occur at later local times as By becomes increasingly negative, although the situation appears rather confused for strongly positive By. In the vicinity of the morning reversal, although data are scarce under all conditions, flows are more frequently observed when By is positive. The effects are more clearly seen in Figures 11 and 12 which illustrate the variation of the SABRE flows at 64 degrees north averaged over all positive and negative values of Bz (Figure 11) and all positive and negative values of By (Figure 12). The amount of data available at each local time are indicated in the centre of each plot, each concentric circle representing 10 data blocks, each of 15 minutes duration. The flows in the vicinity of the morning reversal for positive By are consistent with the predicted existence of a DPY current system in the ionosphere in the post-noon sector (Rostoker, 1980).

SUMMARY

It has proved difficult to identify times during which HILAT and SABRE data may be directly compared. For one particular event, on March 1, 1984, the HILAT velocity measurements were quite different from those recorded by SABRE and it is presumed that a parallel electric field existed which prevented the direct mapping of the perpendicular electric fields between the two regions.

A comparison of data from SABRE and the NNSS satellites suggests that F-region scintillations may be associated with regions of reduced electric field in the E-region. This would be consistent with the presence of field-aligned currents de-stabilising the F-region plasma.

The mean plasma convection pattern measured by SABRE is found to be well correlated with the direction of the IMF component Bz, and convection flows are much stronger for negative Bz. The time of the evening reversal is also related to the value of By and occurs at later local times as By becomes increasingly negative.

BIBLIOGRAPHY

M.D.Burrage, J.A.Waldock, T.B.Jones and E.Nielsen
Joint SABRE and STARE radar auroral observations of the high latitude ionospheric convection pattern. Nature, 316, 133-5, 1985.

E.Nielsen and K.Schlegel
A First Comparison of STARE and EISCAT Electron Drift Velocity Measurements. J.G.R., 88, 5745-50, 1983.

T.Robinson
Towards a self-consistent theory of radar aurora, J. Atmos. Terr. Phys., 48, 417-422, 1986.

J.A.Waldock, T.B.Jones and E.Nielsen
Statistics of 1m wavelength plasma irregularities and convection in the auroral E-region., Radio Sci., 20, 709-717, 1985.

T.B.Jones, J.A.Waldock, E.C.Thomas, C.P.Stewart, T.R.Robinson
SABRE radar observations in the auroral ionosphere
AGARD Conf.Proc., 382, 6.4.1-15, Fairbanks, Alaska, 1985.

J.A.Waldock, L.Kersley, N.Wheadon, T.B.Jones
E-Region Convection Flows Observed by SABRE Associated with Scintillation-Producing Irregularities in the F-region
In Preparation, 1987.

CONFERENCE PRESENTATIONS

J.A.Waldock
Aspect Dependence of 1m Plasma Irregularities in the Auroral E-region
Royal Astronomical Society, M.I.S.T meeting, Liverpool, 10-12 April 1985.

W.A.C.Mier-Jedrzejowicz, D.J.Southwood, M.W.Dunlop, R.P.Rijnbeek, M.Six, J.A.Waldock
AMPTE-UKS Magnetometer Measurements at the Earth's Magnetopause: New Insight into Reconnection
RAS M.I.S.T Meeting, Liverpool, 10-12 April, 1985.

T.R.Robinson and J.A.Waldock
Studies of Auroral Radar Aspect Angle Scattering
RAS M.I.S.T Meeting, London, 22 October 1985.

J.A.Waldock and M.D.Burrage
Interplanetary Magnetic Field effects on the High Latitude Convection Pattern.
RAS M.I.S.T meeting, Edinburgh, 8-9 April 1986.

J.A.Waldock
Recent Observations of the Radar Aurora Using SABRE
UK URSI meeting, University of Birmingham, 8-9 July 1986.

FIGURE CAPTIONS

Figure 1. Illustrating the SABRE viewing area.

Figure 2. The ground track of the HILAT satellite on March 1 1984 during the pass over SABRE

Figure 3a,b. These figures illustrate the data recorded by HILAT during the event.

Figure 4a,b. Illustrating the HILAT and SABRE velocity comparisons.

Figure 5. A sequence of SABREplots during the HILAT pass.

Figure 6. Scintillation measurements from NNSS on 26 August 1985

Figure 7. SABRE data recorded during the pass by NNSS.

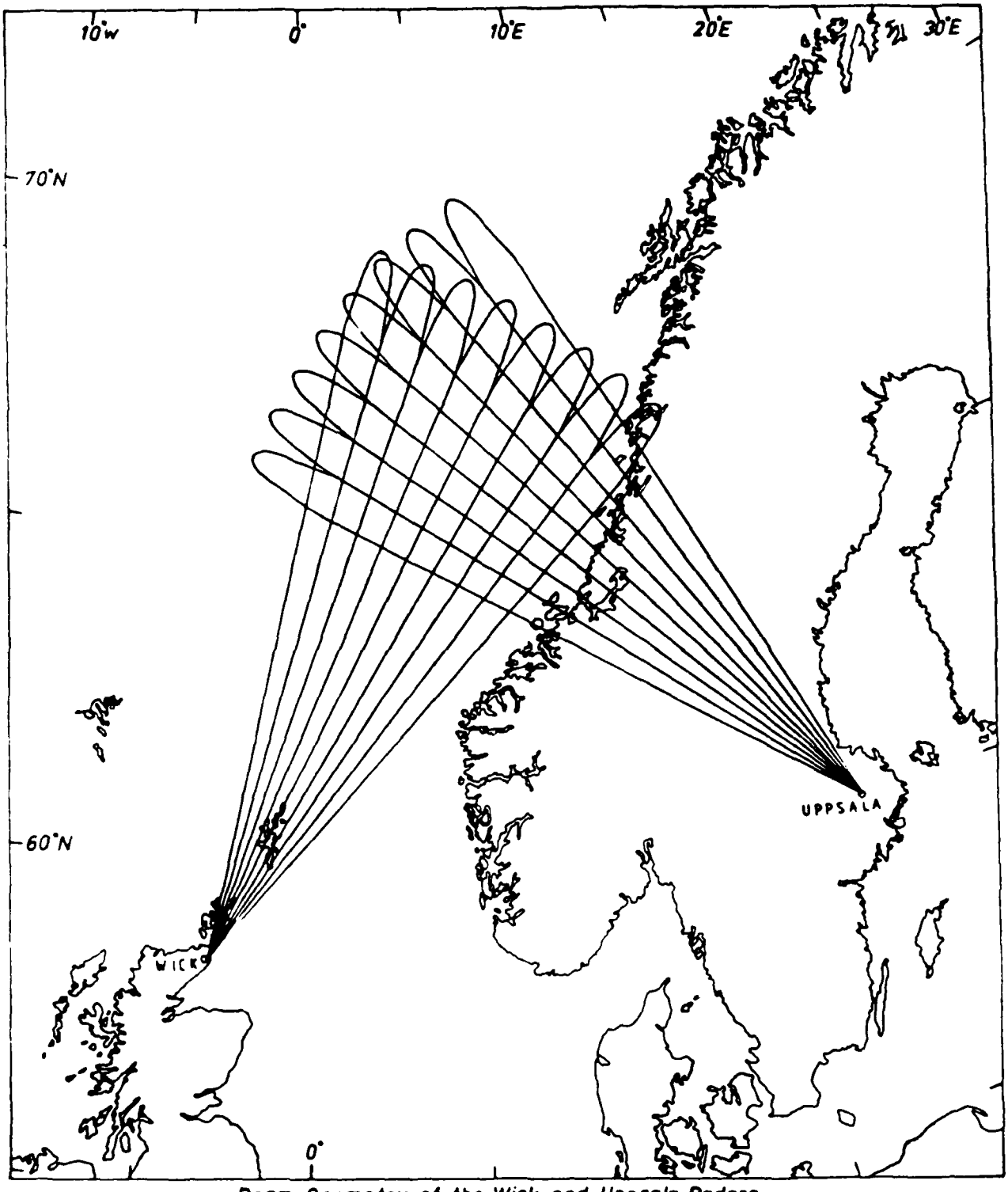
Figure 8. Illustrating the average SABRE convections flows as a function of Kp.

Figure 9. Illustrating the average SABRE convection flows as a function of IMF Bz.

Figure 10. As figure 9 but for IMF By.

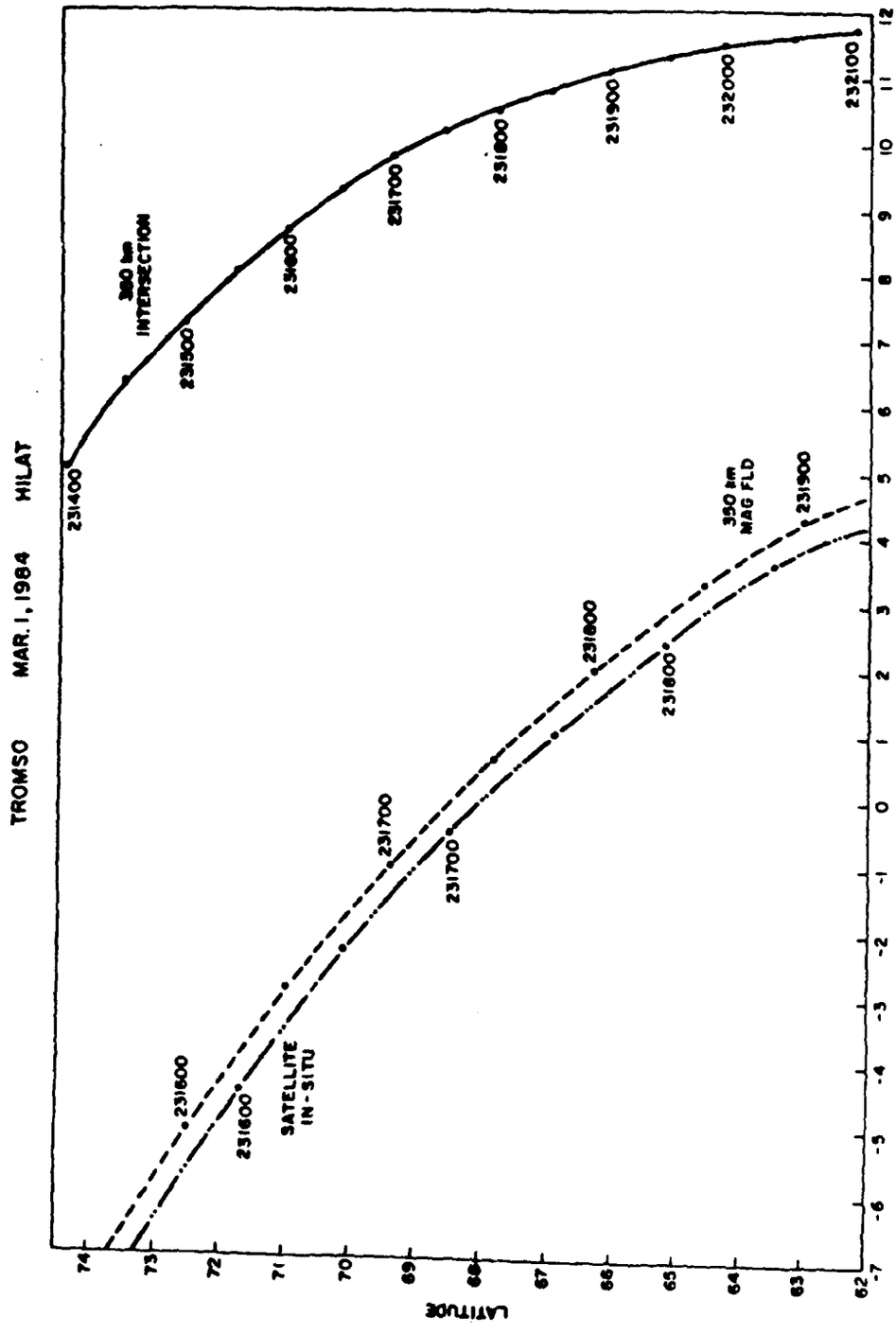
Figure 11. Illustrating the SABRE convection flows at 64 degrees north for (a) Bz < 0 and (b) Bz >0 for all By.

Figure 12. As figure 12 but for By.



Beam Geometry of the Wick and Uppsala Radars

Figure 1


TROMSO MAR. 1, 1984 HILAT
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232000
232100
350 km MAG FLD
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231700
231600
SATELLITE IN-SITU
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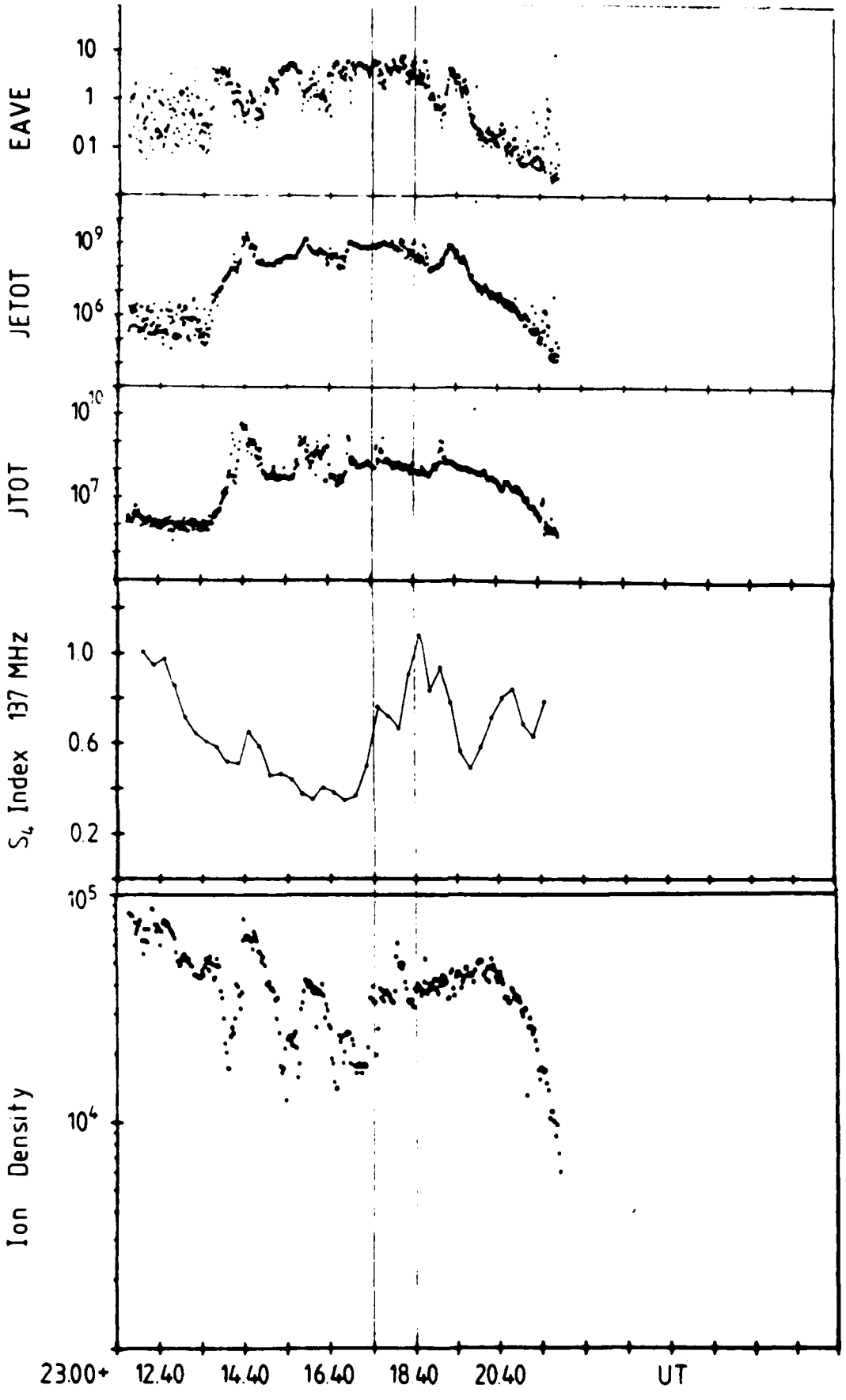
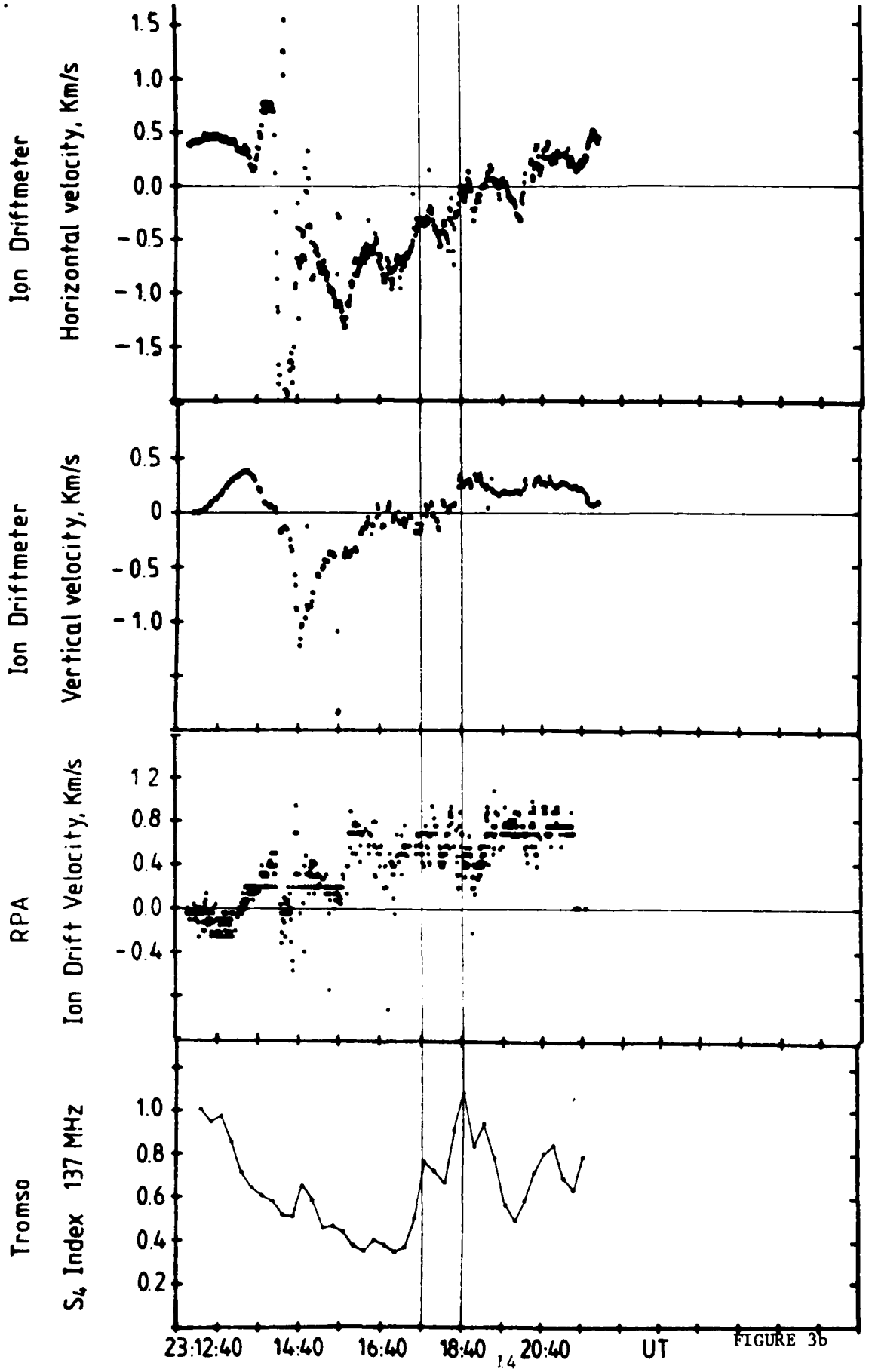
Figure 2



HILAT Day 61 1984

Figure 3a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-0.5
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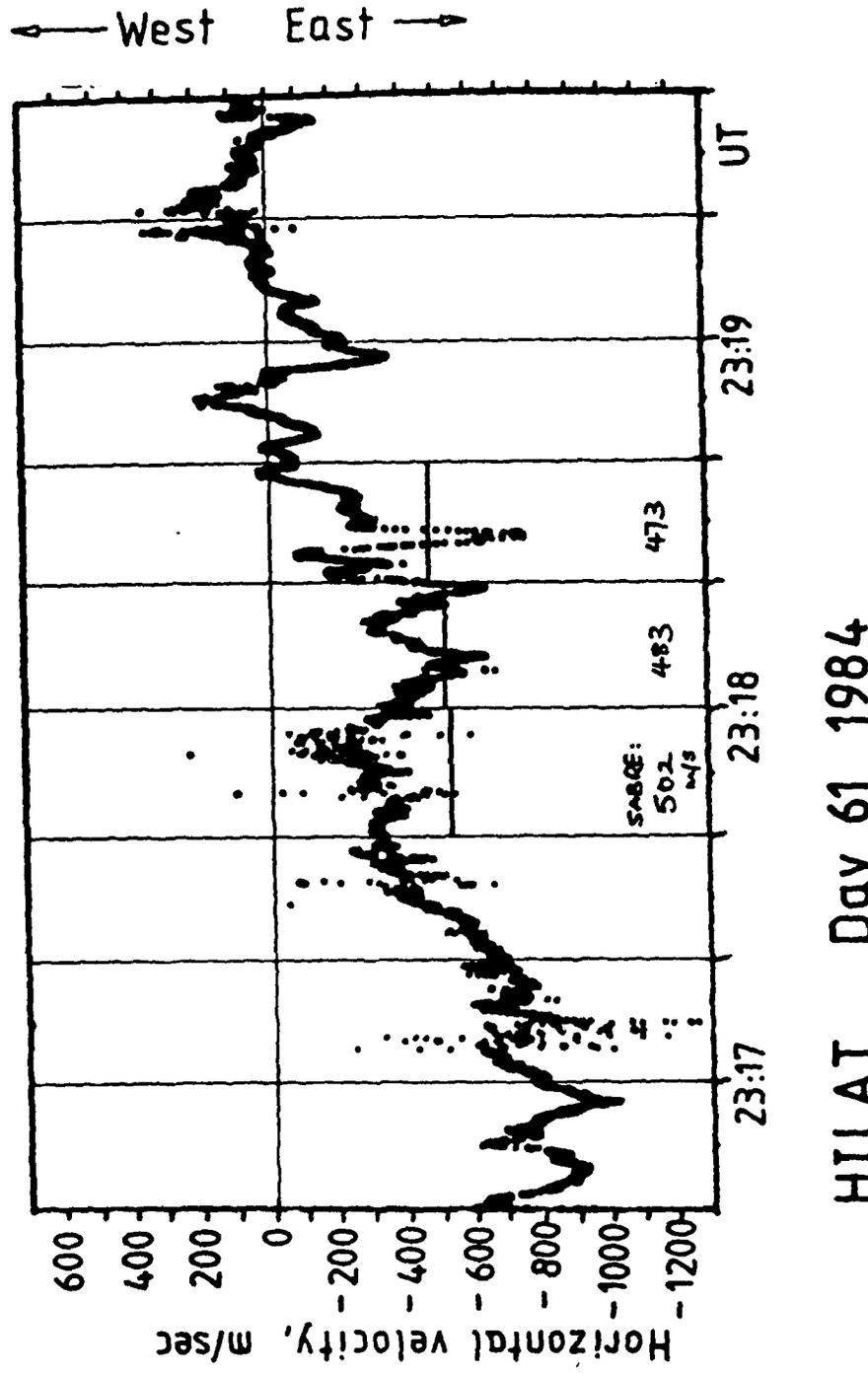
FIGURE 3b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HILAT Day 61 1984

Figure 4a

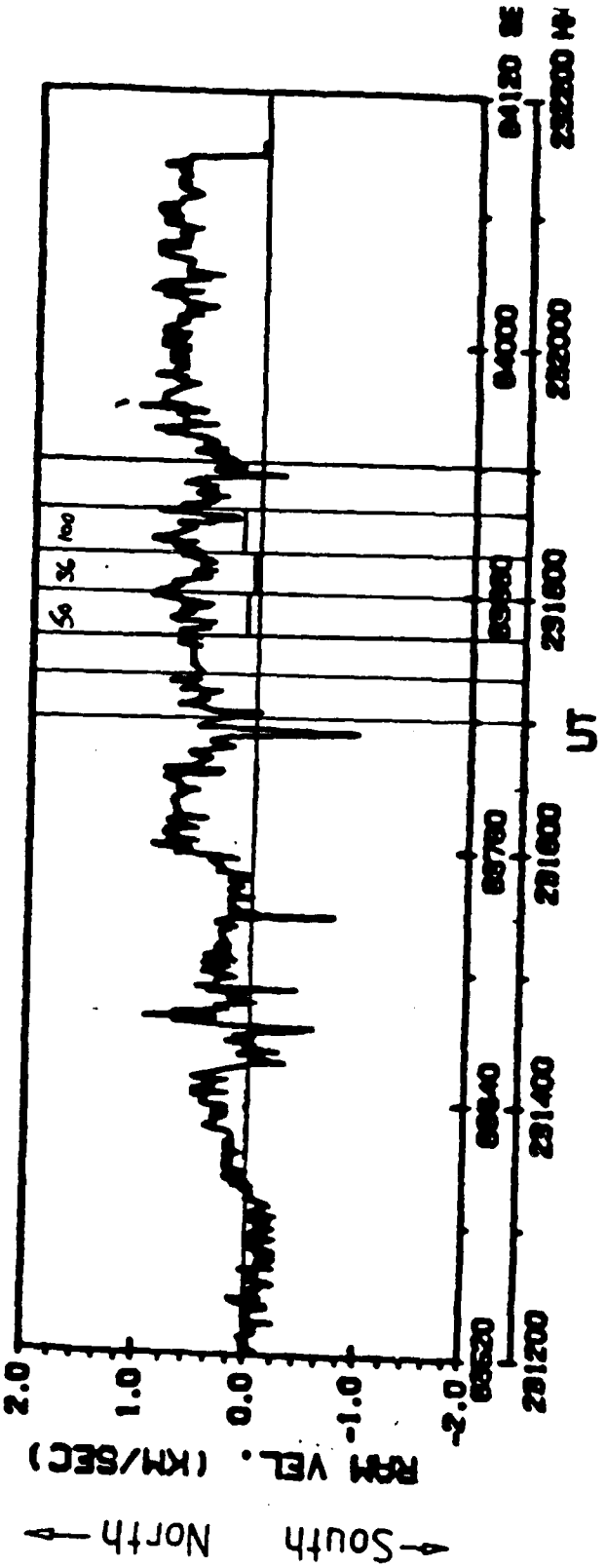
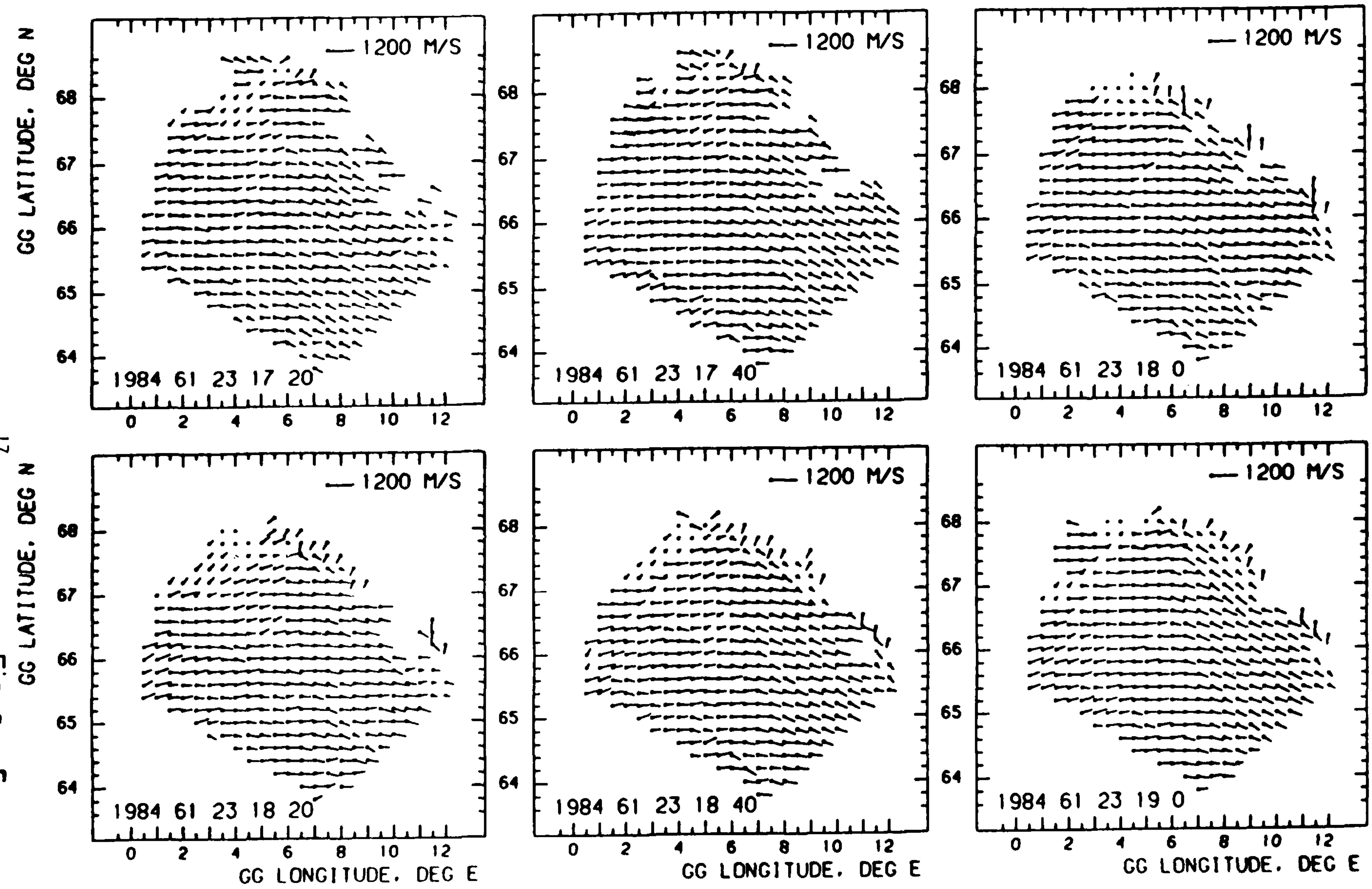


Figure 4b

SABRE IRREGULARITY DRIFT VELOCITIES



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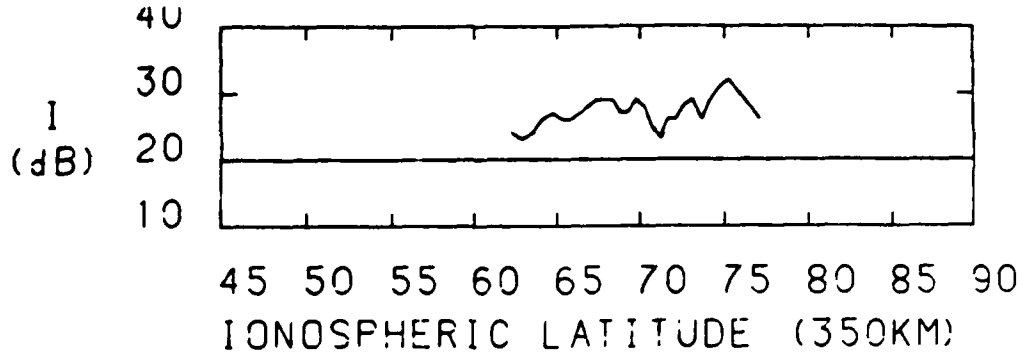

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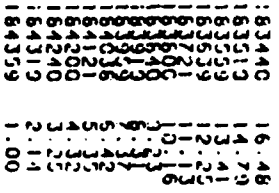

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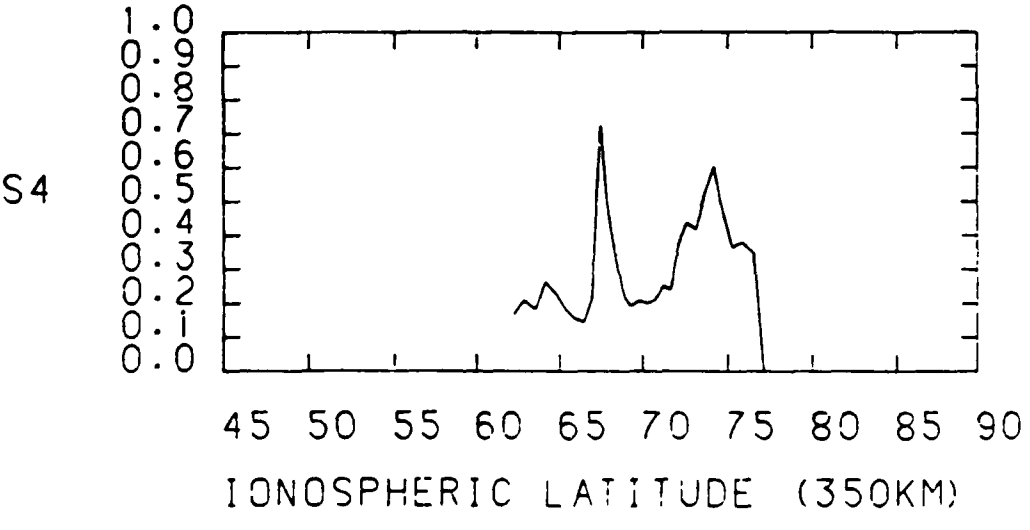


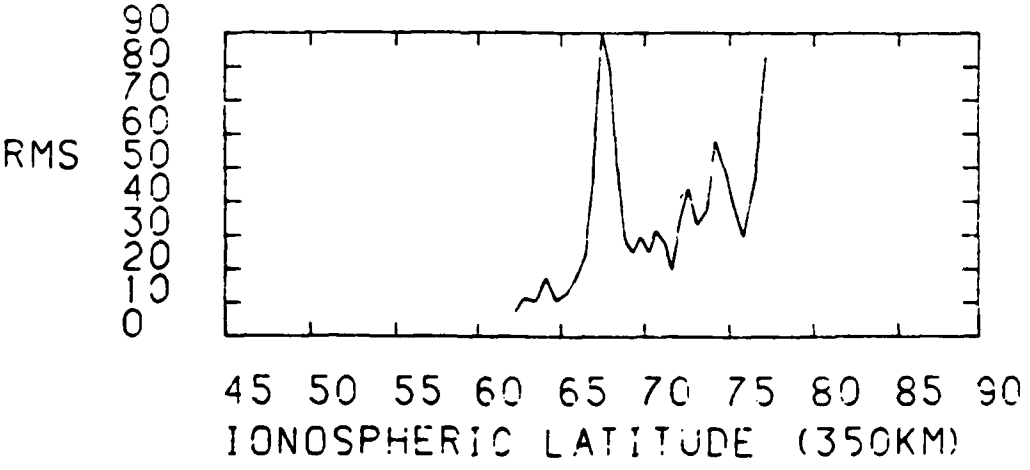
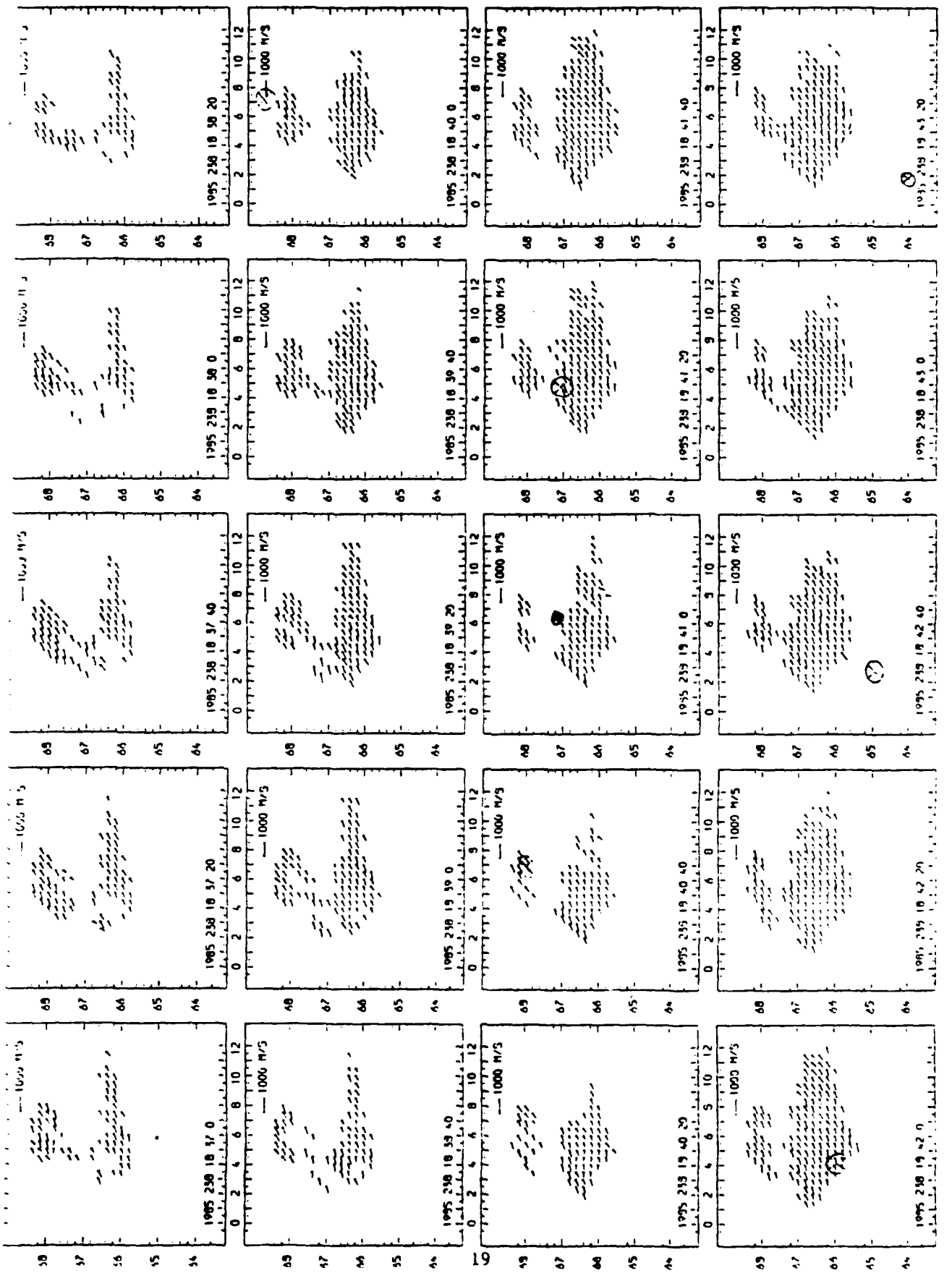
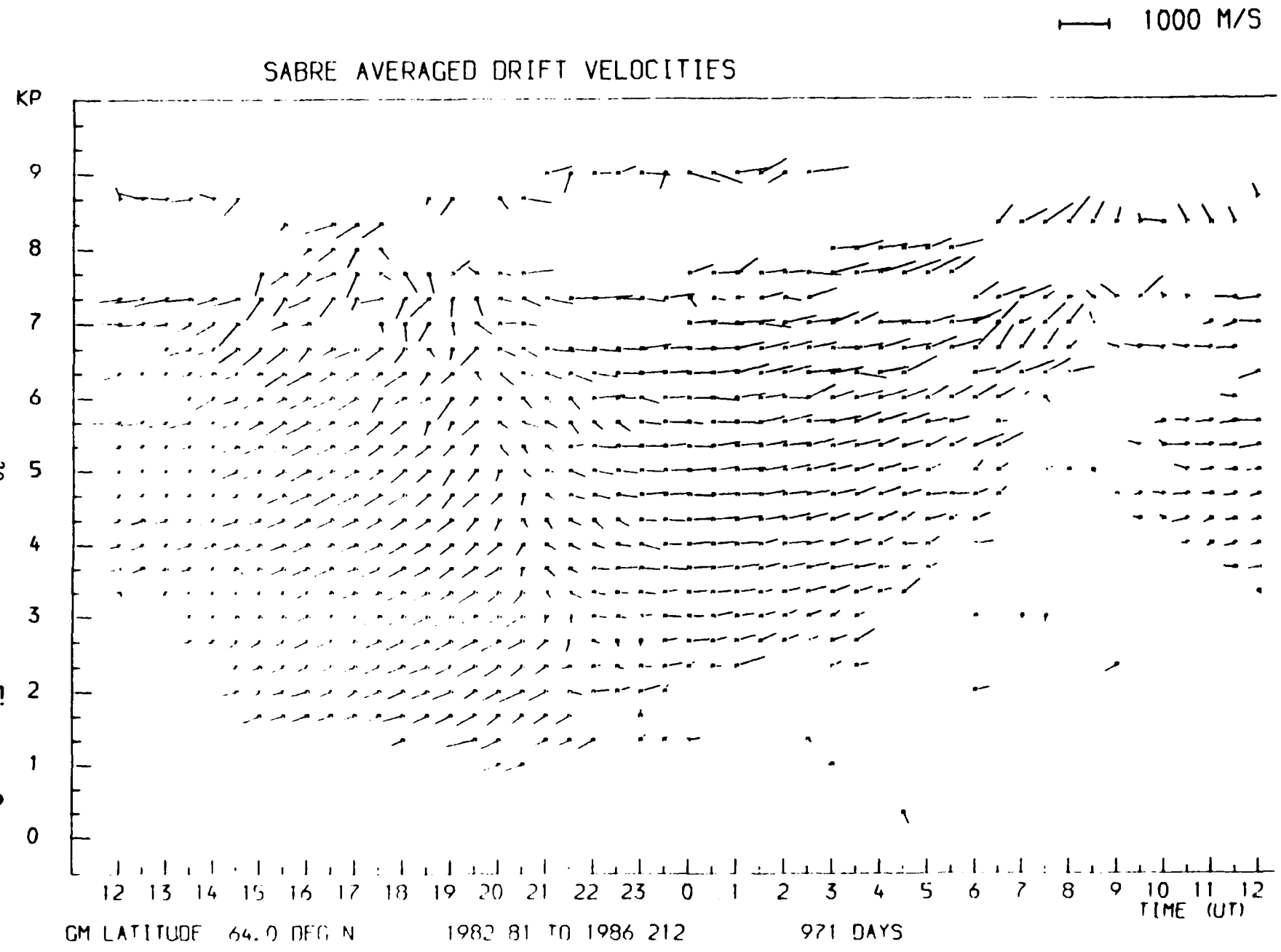


Figure 6

Figure 7

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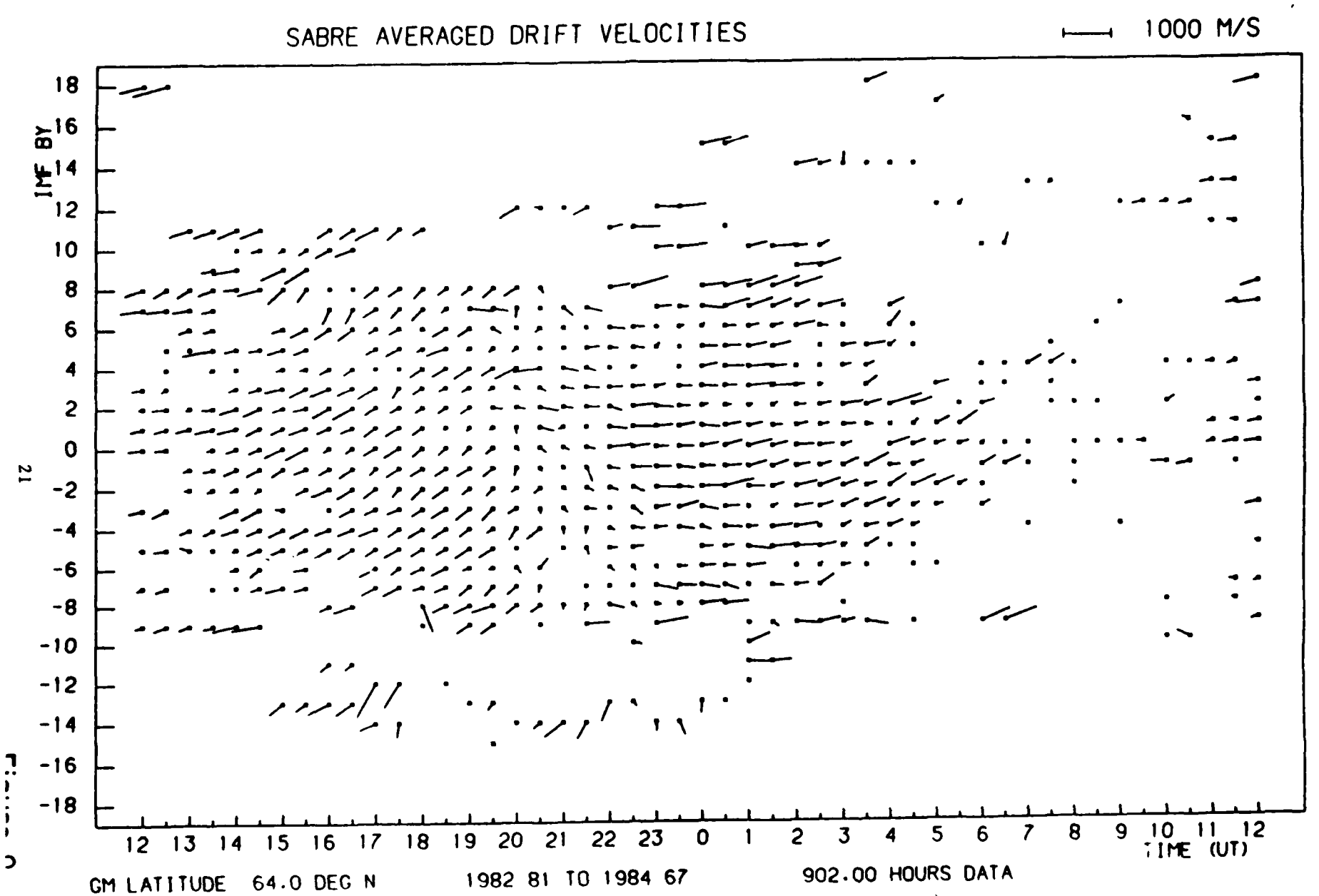
971 DAYS

Figure 8


SABRE AVERAGED DRIFT VELOCITIES
1000 M/S
IMF BY
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
TIME (UT)
GM LATITUDE 64.0 DEG N
1982 81 TO 1984 67
902.00 HOURS DATA

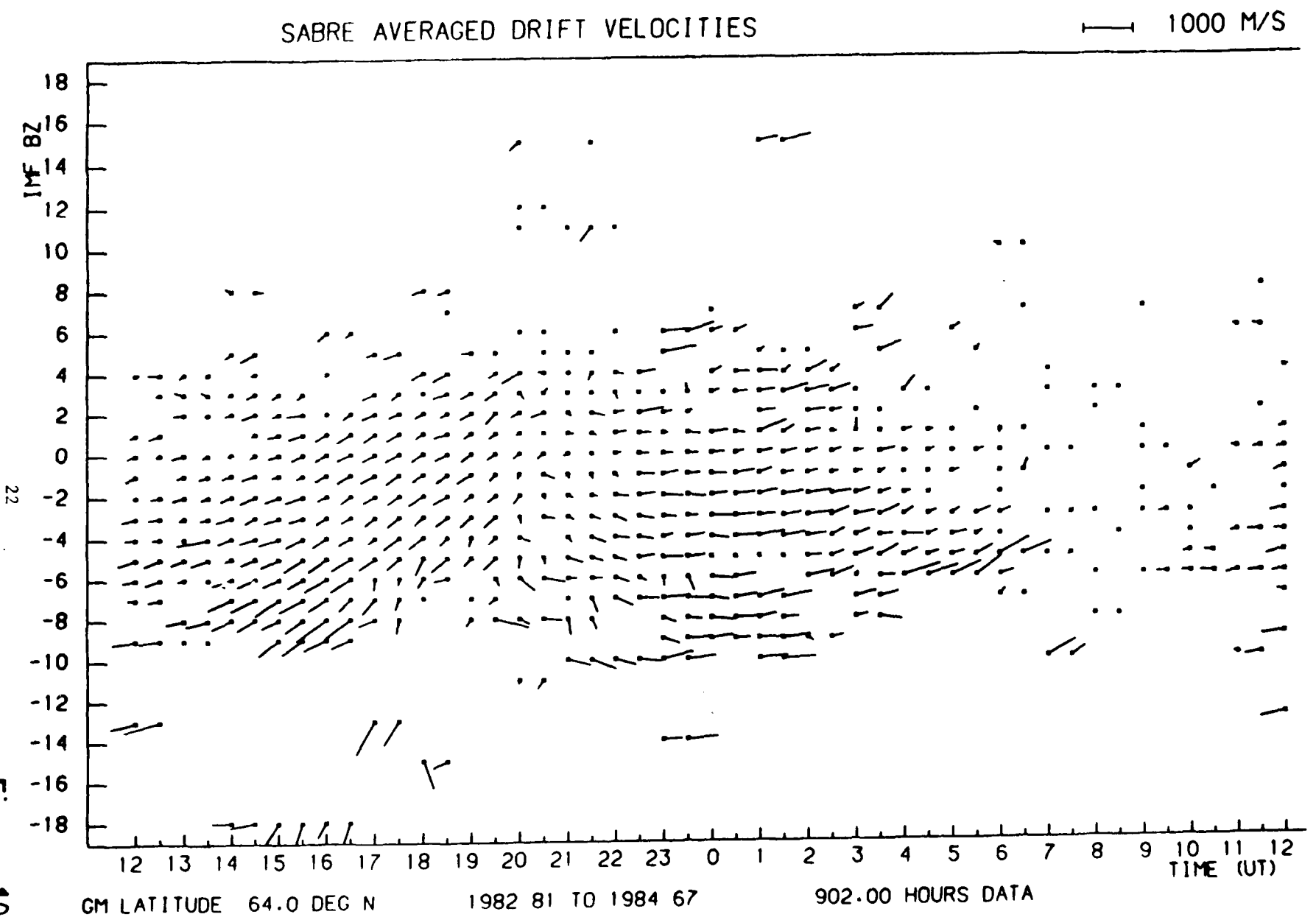
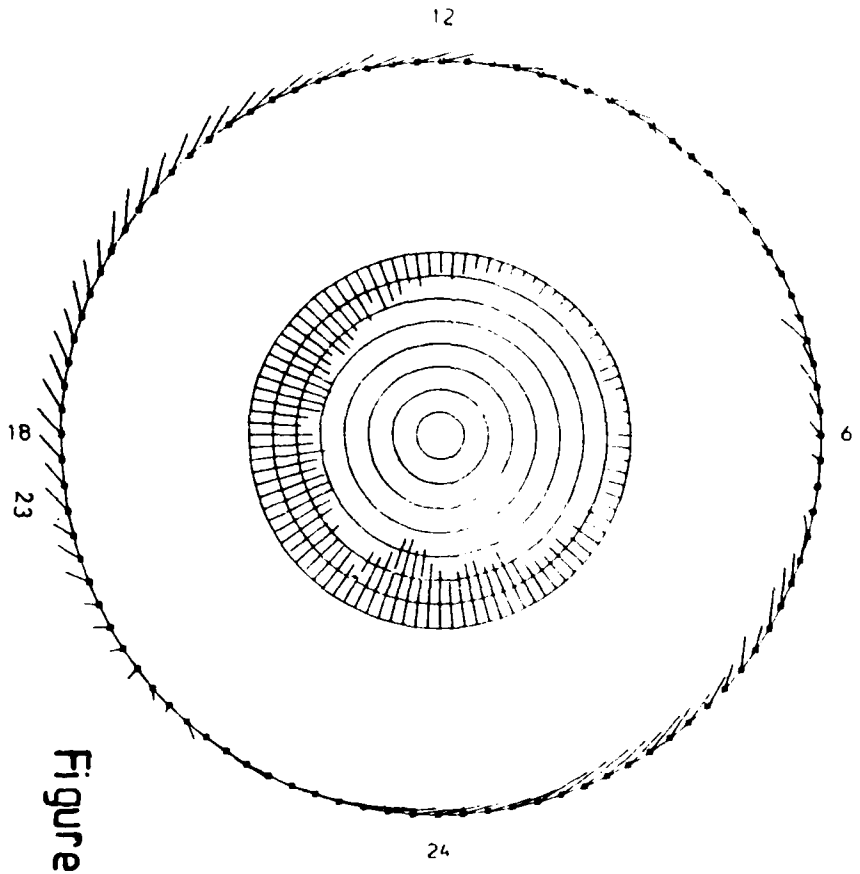
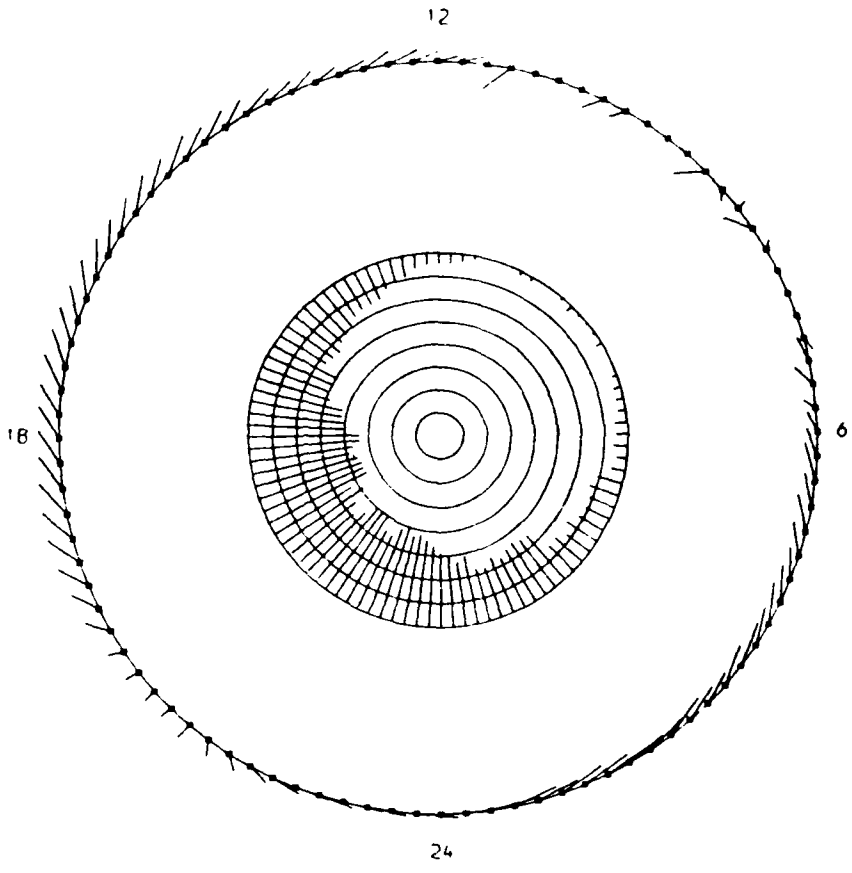

SABRE AVERAGED DRIFT VELOCITIES
1000 M/S
IMF BZ
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12
TIME (UT)
GM LATITUDE 64.0 DEG N
1982 81 TO 1984 67
902.00 HOURS DATA

Figure 10



BY > 0.0 ALL BZ

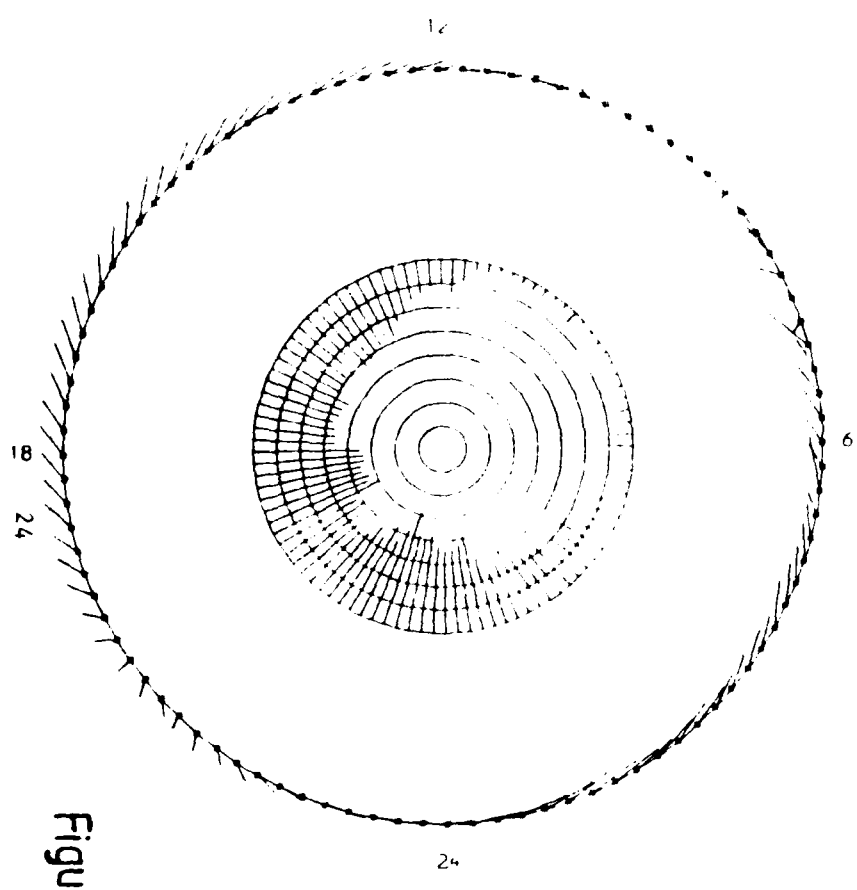
420.50 HOURS DATA



BY < 0.0 ALL BZ

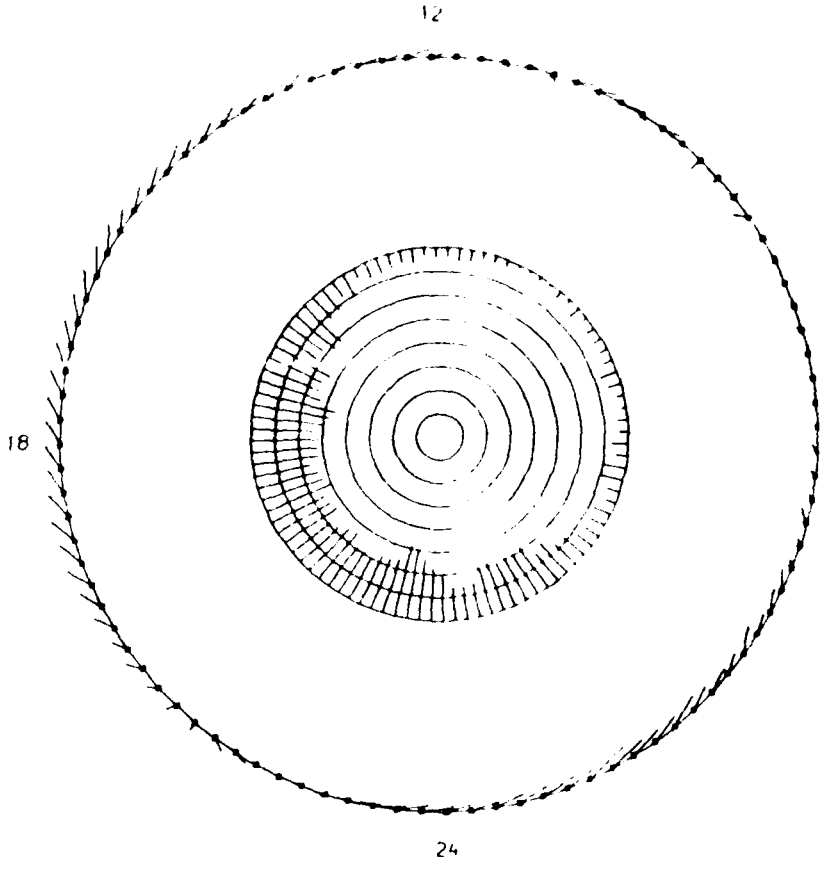
488.25 HOURS DATA

Figure 11



ALL BY BZ < 0.0

565.00 HOURS DATA



ALL BY BZ > 0.0

351.25 HOURS DATA

Figure 12


ATE
MED
8